CHAPTER 6

AERIAL DISTRIBUTION LINES

6-1 General.

Aerial lines will be provided in all areas as established in chapter 5. In order to use the same poles for both aerial distribution and roadway lighting and to avoid interference with possible future projects, consideration will be given to installing pole lines adjacent to roadways.

a. Symbols and codes. For uniformity, symbols will comply with ANSI Y32.9. Installation will comply with the requirements of the NESC for Grade B construction and the NEC as required. The loading district will be that applying to the location of the installation as required by the NESC. Where state safety rules are predominantly accepted, such rules may be used provided they are at least as stringent as those of the NESC.

b. Circuit configurations. Typical circuit configurations and details are provided later in this chapter as a general guide in the design. In addition, publications of the Rural Electrification Administration (REA) will be helpful.

c. Other conditions. Service conditions are covered in chapter 1. Special items such as overhead grounding conductors, grounding, and surge protection are covered in chapter 9. Other conditions will follow the guidelines established by the NESC, the REA, or the local utility as applicable.

6-2. Installation Considerations.

Design of span lengths for aerial lines will be based on such factors as conductor sizes, conductor loadings (conductor weight, wind loading, and ice loading), and load density. Rural area design will be predicated on the most economical span length for the terrain, NESC loading area, conductor size and strength, functional use, and the requirements of joint-use communication lines. Designs for areas such as military base housing, administration, maintenance, and support areas will consider area functional use, span length for the terrain, NESC loading area, conductor size and strength, and the requirements of joint-use communication lines, street and area lighting. Distribution criteria for ammunition plant or process facilities will be based on all of the above and include the requirements of AMCR-385-100. No more than two medium-voltage circuits will be installed on one pole. Switches to facilitate the transfer of load will be provided where circuitry makes this provision economically justifiable. Pole line configuration will include provisions for raptor protection in accordance with Federal and state laws. Consult REA Bulletin 61-10, “Protection of Bald and Golden Eagles from Powerlines.” The requirement for wooden cross-arm braces should be verified for each state and land area in accordance with the Bald Eagle Protection Act of 1940 (16 U.S.C. 688 et seq.) as amended; the Endangered Species Act of 1973 (87 Stat. 1064); and Migratory Bird Treaty of 1918 (16 U.S.C. 703 et seq.) as amended. Sources include the Bureau of Land Management, U.S. Department of the Interior and Federal, state and local land management or wildlife conservation agencies.

6-3. Conductors.

a. Sizes. Where possible, conductor sizes will be limited to a maximum of No. 4/0 AWG copper or equivalent aluminum. Conductor sizes above No. 4/0 AWG copper or equivalent aluminum will be justified by an economic analysis of the alternatives (such as additional circuits or a higher distribution or sub-transmission voltage). The economical minimum conductor size for circuits serving administrative, support and housing areas is No. 2 AWG hard down copper or equivalent aluminum. For small, isolated loads a minimum size of No. 6 AWG copper or equivalent aluminum will be used.

b. Material. Aluminum conductor steel reinforced (ACSR), aluminum alloys, or hard-drawn copper (CU) may be used for medium-voltage lines. Low-voltage conductors may be of aluminum alloys with ACSR messengers or of copper. However, the selection of copper or aluminum will be justified based upon an analysis using life, environmental, and cost factors.

(1) *Type of aluminum alloys.* In their standards and data publications, the Aluminum Association recognizes three alloys of aluminum as suitable for electric conductors. All-aluminum-conductors, formerly known as hard-drawn aluminum or EC grade are now designated as alloy 1350-H19 and the acronym to be used will be AAC. This alloy with a 61 percent copper conductivity is not a preferred type because of the alloy’s low inherent tensile strength. The intermediate strength (5005-H19), alloy will not be used since the conductivity is only one percent greater than the high-strength alloy. The high-strength

6201-T81 (acronym AAAC) alloy with a 52.5 percent copper conductivity is often used as a substitute for ACSR where problems of corrosion have resulted because of the combination of both aluminum and steel in ACSR conductors.

(2) *Use of other conductors.* Special conductors such as copper-clad steel may be used where the application warrants. Conductor selection, where corrosive or salt-laden atmospheres are encountered, may require investigation. The determination of acceptable conductors for special atmospheres will be based on evaluations which will consider local utility practices. Table 6-1 indicates physical properties of conductors for commonly used materials.

c. Conductor insulation. Most medium-voltage conductor installations use bare conductors. Where the use of insulated cable has been justified for medium-voltage lines, the insulation will conform to the requirements applying to underground conductors covered in chapter 7. Messenger wire composition and weatherproof covering, for low-voltage lines will be in accordance with applicable ICEA/NEMA requirements.

d. Sags and tensions. The maximum tension in a span is limited by the strength of the wire and

Conductor material[a]	ASTM standard number	Size AWG	Size kcmil	Number of strands	Diameter inches D_c	Weight lb/ft W_c	Area in² A_c	breaking strength lb	Ampacity[d&e] amperes A
CU (copper, hard-drawn) $E = 17 \times 10^6$ $X = 9.4 \times 10^6$	B1 or B8	6	26.2	Solid	0.162	0.079	0.021	1,280	91
		4	41.7	7	0.232	0.129	0.033	1,940	141
		2	66.4	7	0.292	0.205	0.052	3,042	186
		1	83.7	7	0.328	0.258	0.066	3,804	220
		1/0	105.6	7	0.368	0.326	0.083	4,752	245
		2/0	133.1	7	0.414	0.411	0.105	5,926	283
		4/0	211.6	7	0.527	0.653	0.166	9,154	385
AAC (all-aluminum-conductor, 1350-H19) $E = 10 \times 10^6$ $X = 12.8 \times 10^6$	B231	4	41.7	7	0.232	0.039	0.033	881	100
		2	66.4	7	0.292	0.062	0.052	1,350	137
		1/0	105.6	7	0.368	0.099	0.083	1,990	180
		2/0	133.1	7	0.414	0.125	0.105	2,510	220
		3/0	167.8	7	0.464	0.158	0.132	3,040	260
		4/0	211.6	7	0.522	0.199	00160	3,830	280
		--	336.4	19	0.666	0.316	0.264	6,150	400
AAAC (all-aluminum-alloy-conductor, 6201-T81 $E = 10 \times 10^6$ $X = 12.8 \times 10^6$	B399	4	48.7	7	0.250	0.046	0.038	1,760	150
		2	77.4[b]	7	0.316	0.073	0.061	2,800	200
		1/0	123.3	7	0.398	0.116	0.097	4,460	270
		2/0	155.4	7	0.477	0.146	0.122	5,390	315
		3/0	195.7	7	0.502	0.184	0.154	6,790	365
		4/0	246.9	7	0.563	0.232	0.194	8,560	420
		--	394.5	19	0.720	0.370	0.310	13,300	570
ACSR[c] (aluminum-conductor-steel-reinforced) $E = 11.5 \times 10^6$ $X = 10.5 \times 10^6$	B232	4	41.7	6/1	0.257	0.067	0.041	2,290	112
		2	66.4	6/1	0.316	0.091	0.061	2,850	147
		1/0	105.6	6/1	0.398	0.145	0.097	4,380	194
		2/0	133.1	6/1	0.447	0.183	0.122	5,300	220
		3/0	167.8	6/1	0.502	0.231	0.154	6,620	252
		4/0	211.6	6/1	0.563	0.291	0.194	8,350	282
		--	336.4	26/7	0.720	0.463	0.307	14,100	360

[a] E = final modulus of elasticity in lb/in², X = final coefficient thermal expansion per degrees F.
[b] Size of AAAC is approximately 15 percent larger than AAC to give equivalent current-carrying capacity.
[c] Strength given for ACSR/GA. First number denotes number of aluminum strands, second number denotes number of steel strands.
[d] Current ratings for CU, AAC, & ACSR based on: Copper conductivity 98.0% IACS; aluminum conductivity 61.0% IACS; average temperature rise 30° C above ambient temperature 40° C; frequency 60 Hz.; horizontal position; outdoors; wind velocity 2 feet per second, crosswise; 18 inch minimum line spacing.
[e] Current ratings for AAAC based on: ASTM minimum conductivity 52.5% IACS; average temperature rise 50° C above ambien temperature 25° C; frequency 60 Hz.; horizontal position; outdoors; wind velocity 2 feet per second, crosswise; 18 inch minimum line spacing.

Table 6-1. Conductors Materials-Physical Properties.

its supporting elements. The NESC permits conductor sags, such that for ice and wind loadings applying, the tension of the conductor must not exceed 60 percent of the conductor's rated breaking strength. Also, the tension at 60 degrees F (15 degrees C), without external load, will not exceed 35 percent of the initial unloaded tension and 25 percent of the final unloaded tension. In the case of conductors having a triangular cross section, such as cables composed of three wires, the final unloaded tension at 60 degrees F (15 degrees C) will not exceed 30 percent of the rated breaking strength of the conductor. Refer to the NESC for specific and detailed requirements regarding the application of aerial distribution lines. Both under normal and maximum ice and wind conditions, any conductor will not be loaded beyond limits of safety. In some areas, it may be common practice to reduce the maximum loaded tension to 40 percent or less.

(1) *Initial sags.* Typical initial stringing sags are given in table 6-2 for various conductor materials, sizes, and loading districts for a 200-foot span, since this is a commonly used ruling span. For other ruling spans, manufacturers will be consulted. A ruling span is an assumed "design span" that assures average tension throughout a line of nonuniform span lengths between deadends and can be calculated exactly by the following equation where S is distance between spans, from 1 span up to n spans. The large variations in temperatures, wind, and ice conditions encountered at various military installations makes it extremely important that conductors be properly sagged. The copper-equivalent sizes, given in table 6-2, are based generally on assuming that aluminum conductors two sizes larger than copper are equivalent in ampacity. To sag conductors properly, the conductor manufacturer's published data must be used.

$$\text{Ruling span—} \frac{(S_1^3 + S_2^3 + S_3^3 + \ldots S_n^3)^{1/2}}{(S_1 + S_2 + S_3 = \ldots S_n)^{1/2}} \qquad \text{(eq 6-1)}$$

(2) *Final sags and tensions.* The final loaded tension data shown in table 6-3 indicates final

Conductors		Stringing temperature 30°F			Stringing temperature 60°F			Stringing temperature 90°F		
		Loading districts			Loading districts			Loading districts		
Material	AWG copper (aluminum)	Light	Medium	Heavy	Light	Medium	Heavy	Light	Medium	Heavy
					Stringing sag feet					
CU		1.2	1.3	1.5	1.6	1.8	2.0	2.0	2.3	2.6
AAC		0.8	0.9	1.1	1.1	1.3	1.7	1.6	2.0	2.5
AAAC	4/0(336.4)	0.4	0.5	0.7	0.5	0.7	0.9	0.7	1.0	1.3
ACSR		0.5	0.6	0.8	0.6	0.7	1.0	0.7	1.0	1.4
CU		1.2	1.4	1.5	1.5	1.8	2.0	2.0	2.3	2.6
AAC		0.8	0.9	1.2	1.1	1.4	1.8	1.8	2.2	2.7
AAAC	2/0(4/0)	0.4	0.5	0.6	0.5	0.7	0.9	0.7	0.9	1.3
ACSR		0.6	0.7	0.8	0.7	0.9	1.0	0.9	1.2	1.4
CU		1.2	1.5	1.5	1.5	1.9	2.0	2.0	2.5	2.6
AAC		0.9	0.9	1.7	1.5	1.4	2.5	2.1	2.2	3.3
AAAC	1/0(3/0)	0.4	0.5	0.6	0.5	0.7	0.9	0.7	0.9	1.3
ACSR		0.6	0.7	0.7	0.7	0.9	1.0	0.9	1.2	1.4
CU		1.2	1.5	1.5	1.5	2.0	2.0	2.0	2.6	2.6
AAC		0.8	0.9	2.2	1.0	1.3	3.0	1.7	2.1	3.8
AAAC	1(2/0)	0.4	0.5	0.6	0.5	0.7	0.9	0.7	0.9	1.3
ACSR		0.6	0.7	0.7	0.7	0.8	0.9	0.9	1.2	1.3
CU		1.2	1.7	1.5	1.5	2.2	2.0	2.0	2.8	2.6
AAAC		0.7	0.9	3.5	1.1	1.3	4.2	1.7	2.1	4.8
AAAC	2/(1/0)	0.4	0.5	0.6	0.5	0.6	0.8	0.6	0.8	1.1
ACSR		0.5	0.6	0.6	0.7	0.8	0.8	0.8	1.1	1.1
CU		1.7	2.1	2.7	1.8	2.7	3.2	2.3	3.3	3.8
AAAC		0.7	1.0	5.8	0.9	1.6	6.3	1.5	2.4	6.7
AAAC	4(2)	0.4	0.5	0.6	0.5	0.6	0.7	0.6	0.8	1.1
ACSR		0.5	0.6	0.6	0.6	0.7	0.7	0.7	1.0	1.0
CU		1.5	--	--	2.0	--	--	2.5	--	--
AAC		0.7	3.0	9.7	0.9	3.7	10.0	1.4	5.0	10.2
AAAC	6(4)	0.4	0.5	0.9	0.5	0.6	1.4	0.6	0.8	2.1
ACSR		0.5	0.5	0.9	0.6	0.7	1.4	0.7	0.9	2.0

Table 6-2. Initial Stringing Sags for 200-Foot Spans.

loaded tensions and sags for conductors which were initially strung to the sags of table 6-2. Sags are a maximum at the indicated loading conditions. Tensions will be less at higher temperatures when wind and ice loads do not apply (final unloaded conditions).

(3) *Unusual loading conditions.* The NESC stipulates loading and installation requirements for normal conditions, as shown in table 6-3; however, many areas will be subjected to climatic conditions much more severe than those listed, in resepct to both wind and ice loads. In these instances, a complete analysis will be required to determine acceptable sagging versus strength. An example of an aerial conductor strength analysis is given in figure 6-1. Pole line analyses will be provided and will show calculations for pole strengths, guying, span length, and sags. This type of calculation requires making an assumption (in this case that conductor sag equal 2.06 feet) and then checking the validity of the assumption, which can be tedious and time-consuming. Conductor manufacturers have computer programs which have been developed to perform these calculations. The assumed value of 2.06 feet of sag and 3,350 pounds tension are different from the values given in table 6-3 where the values listed are 2.4 feet of sag and 2,870 pounds tension. The variation results because of elastic creep; however, the variation in values of about 15 percent, in this case, provides a more conservative design or an additional safety factor.

e. Conductors for Air Force installations.

(1) Minor extensions to systems using copper conductors shall be made with copper.

(2) Major extensions to existing systems and new systems shall be of bare hard drawn copper, aluminum, or steel reinforced aluminum.

(3) Self-supporting aerial cable with insulated cable lashed to the neutral messenger or individual insulated cables supported from the messenger with insulated spacers may be utilized if approved

Conductors		Loading districts					
		Light: 9 lb/ft^2 horizontal wind, no ice, 30°F		Medium: 4 lb/ft^2 horizontal wind, 1/4-inch radial ice, 15°F		Heavy: 4 lb/ft^2 horizontal wind, 1/2-inch radial ice, 0°F	
Material	AWG copper (aluminum)	Tension lb	Sag ft	Tension lb	Sag ft	Tension lb	Sag ft
CU		2,900	a	3,000	a	3,350	a
AAC	4/0(336.4)	1,675	1.9	2,060	2.2	2,620	2.8
AAAC		3,460	1.0	3,610	1.4	3,970	2.0
ACSR		3,670	1.0	3,850	1.4	4,260	1.9
CU		1,800	a	1,950	a	2,350	a
AAC	2/0(4.0)	1,180	2.1	1,490	2.5	1,920	3.3
AAAC		2,270	1.2	2,430	1.6	2,780	2.4
ACSR		2,250	1.2	2,460	1.7	2,870	2.4
CU		1,450	a	1,550	a	2,000	a
AAC	1/0(3/0)	1,130	1.9	1,270	2.7	1,520	4.0
AAAC		1,820	1.3	1,990	1.8	2,340	2.7
ACSR		1,810	1.4	2,020	1.9	2,430	2.7
CU		1,200	a	1,300	a	1,700	a
AAC	1(2/0)	840	2.3	1,110	2.9	1,260	4.5
AAAC		1,475	1.4	1,650	2.1	1,980	3.0
ACSR		1,480	1.5	1,690	2.1	2,078	2.9
CU		940	a	1,050	a	1,450	a
AAC	2(1/0)	700	2.4	960	3.2	1,000	5.5
AAAC		1,230	1.5	1,400	2.3	1,720	3.2
ACSR		1,240	1.5	1,440	2.3	1,800	3.2
CU		540	a	720	a	1,000	a
AAC	4(2)	520	2.7	675	4.1	680	7.5
AAAC		810	1.8	990	2.9	1,280	4.0
ACSR		850	1.8	1,050	2.8	1,370	3.8
CU		350	a	a	a	a	a
AAC	6(4)	380	3.0	440	5.8	440	10.9
AAAC		550	2.0	730	3.6	880	5.5
ACSR		580	2.1	790	3.4	930	5.2

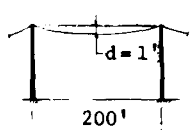
Table 6-3. Final Loaded Tensions for 200-Foot Spans,

USING VALUES BELOW		IN FORMULAS BELOW
w_c	= Conductor weight, unloaded (lb/ft)	$T = \frac{w_c L^2}{8d}$ . . . . (1)
L	= Length of pole spacing (ft)	
d	= Conductor sag (ft)	
T	= Tension (lb)	
ΔL	= Length conductor is greater than pole spacing based on parobolic formula (in)	$\Delta L = \frac{8d^2}{3L} \times 12 = \frac{32d^2}{L}$ . . . . (2)
D_c	= Conductor diameter (in)	$D_n = D_c + (2 \times \text{ice thickness}^a)$ . . (3)
D_n	= Conductor plus NESC additional ice thickness requirement (in)	[a]Ice thickness from NESC table 250-1
W	= NESC wind force requirement (lb/ft^2)	
w_h	= Horizontal loading (lb/ft)	$w_h = \frac{WD_n}{12}$ . . . . (4)
I_w	= Ice weight factor of 0.396 lb/ft per in^2 based on NESC weight of ice (57 lb/ft^3)	
w_i	= Weight of ice (lb)	$w_i = \frac{\pi}{4}(D_n^2 - D_c^2)I_w$ . . . . (5)
w_v	= Vertical loading (lb/ft)	$w_v = W_c + W_i$ . . . . (6)
k	= Constant to be added to resultant from NESC table 251-1	
w_{cl}	= Conductor weight, loaded (lb/ft)	$w_{cl} = (w_v^2 + w_h^2)^{1/2} + k$ . . . . . . (7)
T_s	= Stringing tension (lb)	
T_1	= Tension under NESC loading conditions (lb)	$\Delta T = T_1 - T_s$ . . . . (8)
ΔT	= Increase in loaded tension over stringing tension (lb)	
A_c	= Conductor cross-section (in^2)	
ΔS	= Increase in stress (lb/in^2)	$\Delta S = \frac{\Delta T}{A_c}$ . . . . (9)
E	= Modulus of elasticity of conductor	
ΔL_s	= Increase in length from stress increase (in)	$\Delta L_s = \frac{\Delta S(12L)}{E}$ . . . . (10)
X	= Thermal expansion coefficient per (° F)	
Δt	= Change in temperature between stringing temperature and loaded temperature (° F)	$\Delta L_t = X(\Delta t)(12L)$ . . . . (11)
ΔL_t	= Decrease in length from temperature decrease (in)	

EXAMPLE FOR HEAVY LOADING DISTRICT

INITIAL CONDITIONS

Primary
#4/0 AWG ACSR



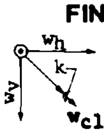
$D_c = 0.563$ in
$A_c = 0.194$ in^2
$W_c = 0.291$ lb/ft
$E = 11.5 \times 10^6$
$X = 10.5 \times 10^{-6}$

60° F stringing temperature

$T_s = \frac{(0.291)(200)^2}{8(1)} = 1{,}455$ lb..(1)

$\Delta L = \frac{32(1)^2}{200} = 0.16"$ ....(2)

FINAL LOADED WEIGHT



$w_h = \frac{4[0.563 + (2 \times 0.5)]}{12}$

$= 0.521$ lb/ft..(3),(4)

$w_v =$

$0.291 + \frac{\pi}{4}(1.56^2 - 0.563^2)(0.396) =$

0.952 lb/ft ....(5),(6)

$w_{cl} =$

$(0.952^2 + 0.521^2)^{1/2} + 0.30 =$

1.38 lb/ft .... (7)

FINAL LOADED CONDITIONS

$T_1{}^a = \frac{(1.38)(200)^2}{8(2.06)} = 3{,}350$ lb...(1)

$\Delta T = 3{,}350 - 1{,}455 = 1{,}895$ lb..(8)

$\Delta S = \frac{1{,}895}{0.194} = 9{,}773$ lb/in^2 .....(9)

$\Delta L_s = \frac{9{,}773(12 \times 200)}{11.5 \times 10^6} = 2.04"$..(10)

$\Delta L_t = 10.5 \times 10^{-6}(60 - 0)(12 \times 200)$
$= 1.51"$ ....(11)

Loaded $\Delta L = 2.04 - 1.51 + 0.16$
$= 0.69"$

Check: $\Delta L = \frac{32(2.06)^2}{200} = 0.68"$...(2)

[a]The value 2.06 in the formula was assumed

Rated breaking strength of conductor = 8,350 lb
NESC requirement for maximum load = 8,350 x 60% = 5,190 lb
3,350 lb (1) < 5,190 lb

Courtesy of Keller & Gannon

Figure 6-1. An Example of an Aerial Conductor Strength Analysis.

by the Host Command coordinated with the Requiring Command (HOST/REQ CMD).

(4) Aluminum conductors shall be terminated in compression type lugs or connectors filled with a high temperature oxide inhibitor compound.

6-4. Poles.

a. *Types*. Solid wood poles will be used for electric distribution lines, while concrete and steel poles will be used for roadway or area lighting circuits carried underground or separately from distribution lines. Concrete or steel poles may be justified for medium-voltage distribution circuits where wood poles do not provide adequate strength, or where climatic conditions cause wood poles to deteriorate rapidly. Laminated wood poles will not be used for electric distribution lines. However, in some instances the surrounding environment may make their installation appropriate for roadway and area lighting applications.

(1) *Wood poles.* Solid wood poles are covered by ANSI 05.1. Pole strengths are designated by classes 1 through 10 for normal strengths and H1 through H6 for higher strengths. These classes establish pole circumference limitations for each class and species of wood.

(2) *Concrete poles.* Normal reinforced concrete poles are not strong enough for the wind and ice loads which prevail in some areas. Either centrifugally spun or cast, prestressed concrete poles are acceptable, but special pole design, based on calculations of pole loads, will be necessary to assure adequate strength. Where strength requirements dictate excessive concrete pole diameters, steel poles will be used.

(3) *Tapered tubular metal poles.* Galvanized steel poles are covered by AASHTO LTS-2, but no classes are given. Aluminum poles are not acceptable, since corrosion may be a problem and aluminum poles do not provide adequate strength.

b. Lengths and strengths. Pole lengths will be selected conservatively, making allowance for the installation of communication lines and the required pole setting depth. Communication space will include allowance for telephone lines, and may include allowance for fire alarm, television, or other signal circuits as required. If at the time of design, exact requirements cannot be determined, a 2-foot space allocation is ample and will be provided on all poles even though present plans do not include telephone lines. Longer poles will be provided in areas where the future installation of additional electric circuits and equipment can be reasonably expected. Pole strengths will meet the NESC requirements for grade “B” construction for the applicable loading district. Since the normal maintenance activity does not have the financial or personnel capabilities of a utility, it may be necessary to use pole strengths greater than code minimums. Table 6-4 indicates pole lengths and classes (strengths) which are considered the minimum for normal use. Poles less than 40 feet in length, or classes 6 through 10, will not be installed for medium-voltage lines. The required pole embedment is dependent upon the loading district and upon soil conditions. A pole length and strength calculation is shown on figure 6-2.

c. Pole-setting depths. In normal firm ground, minimum pole-setting depths will be as shown in table 6-5. In rocky or swampy soil, pole-setting depths will be decreased or increased accordingly.

Table 6-4. Minimum Primary Wood Pole Lengths and Classes

Length feet	Class
40	4 or 5
45	3 or 4
50	2 or 3

Table 6-5. Minimum Pole-Setting Depth.
(Feet and Inches)

Pole Length (Feet)	Straight Pole Lines	Curves, Corners, and Points of Extra Strain	Pole Length (feet)	Straight Pole Lines	Curves, Corners, and Points of Extra Strain
20	5-0	5-0	65	8-6	9-0
25	5-6	5-6	70	9-0	9-6
30	5-6	5-6	75	9-6	10-0
35	6-0	6-0	80	10-0	10-6
40	6-0	6-6	85	10-6	11-0
45	6-6	7-0	90	11-0	11-6
50	7-0	7-6	95	11-6	12-0
55	7-6	8-0	100	12-0	12-6
60	8-0	8-6			

6-5. Circuit Configurations.

Preferred and alternate configurations for tangent construction are shown on figure 6-2. Also shown on this figure are methods of mounting overhead ground wires and locations for primary neutrals when required. Insulation shown on the figures in this chapter is for a nominal 15 kV class.

a. Medium-voltage circuit configurations. Armless and crossarm mounting, shown in figures 6-3 and 6-4 respectively, are both used for open conductors. REA Bulletin 61-12 provides additional details on armless construction. Triangular tangent construction requires the least pole space and is the most economical. Where such a configuration is not suitable, because of special requirements such as the need for an overhead ground wire, vertical tangent construction will be provided. Requirements for overhead ground wires are covered in chapter 9. Crossarm construction as shown on figure 6-4 will be limited to equipment installations, or where use of armless construction would result in excessive pole heights. However, other technical considerations, such as a line with many taps, crossings, or overhead-to-underground transitions, may impact the decision. Also, armless construction requires bucket trucks for maintenance due to loss of climbing space.

(1) *Angles at which guying is required.* Guying requirements for other than in-line circuits are dependent upon the angle of deviation, the size of the conductor, and the loading district. REA pole details show guys for angles of deviation greater than two degrees on armless construction configurations, regardless of conductor size or loading. Local practice may permit larger angles for smaller conductors or vertical construction, but any pole where the angle of deviation of the line exceeds five degrees will be guyed. This requirement applies both to armless and crossarm construction.

(2) *Angles at which changes in configurations apply.* The degree to which the more rigid line-post or pin type insulator support can be used will also vary dependent upon the angle of deviation and the size of the conductor. Suspension insulators can be used for any angle, but are a more expensive installation; therefore, their use will be required only when the line-post or pin type is unsuitable. Normal angles for armless configurations are shown on figure 6-3 and are in agreement with REA pole detail drawings. Table 6-6 indicates normal angles for crossarm configurations related to conductor size.

b. Low-voltage circuit configurations. Low-voltage circuits will be supported by clamping the bare neutral conductor of a neutral-supported secondary aerial cable to a spool/clevis insulator assembly as shown on figure 6-5 or by use of spool insulators on secondary racks supporting insulated phase and neutral conductors. Because of both the space requirements and the unattractive appearance, phase conductors supported on secondary racks will be limited to special circumstances.

6-6. Insulators.

The operating performance of aerial lines is dependent upon the quality of the line insulators. Insulators will be of the wet process porcelain type; the only presently acceptable alternative in an appropriate situation is toughened glass, which is an industry standard only for suspension insulators. Glass is much more susceptible to shattering than porcelain; so where vandalism is a problem, glass will not be permitted. Polymer insulators have some advantages such as light weight and resistance to vandalism; once industry standards are issued, use of polymer units may be considered. Insulators need to provide ample mechanical strength for the expected ice and wind loads and must be capable of withstanding the stresses of lightning and switching surges without damage to the insulators. Operating stresses are increased under atmospheric conditions which causes pollutants to build up on the insulator surface. Various types of insulators are manufactured to meet requirements imposed by different applications. Each type is industry rated by ANSI in classes which establish dimensions and minimum electrical and mechanical performance values.

a. Types. Pin-type, line-post, or suspension insulators will be used for medium-voltage circuits;

Table 6-6. Relation of Crossarm Configuration to Conductor Size.[a]

Maximum conductor size AWG	Tangent angle "A" degree	Minor angle "B" degree	Intermediate angle "C" degrees
4/0	0–1	2–4	5–45
1/0	0–3	4–8	9–45
2	0–5	6–12	13–45
6	0–11	12–24	25–45

[a]Credit: US Corps of Engineers. Angles "A", "B", and "C" are shown on figure 6-3.

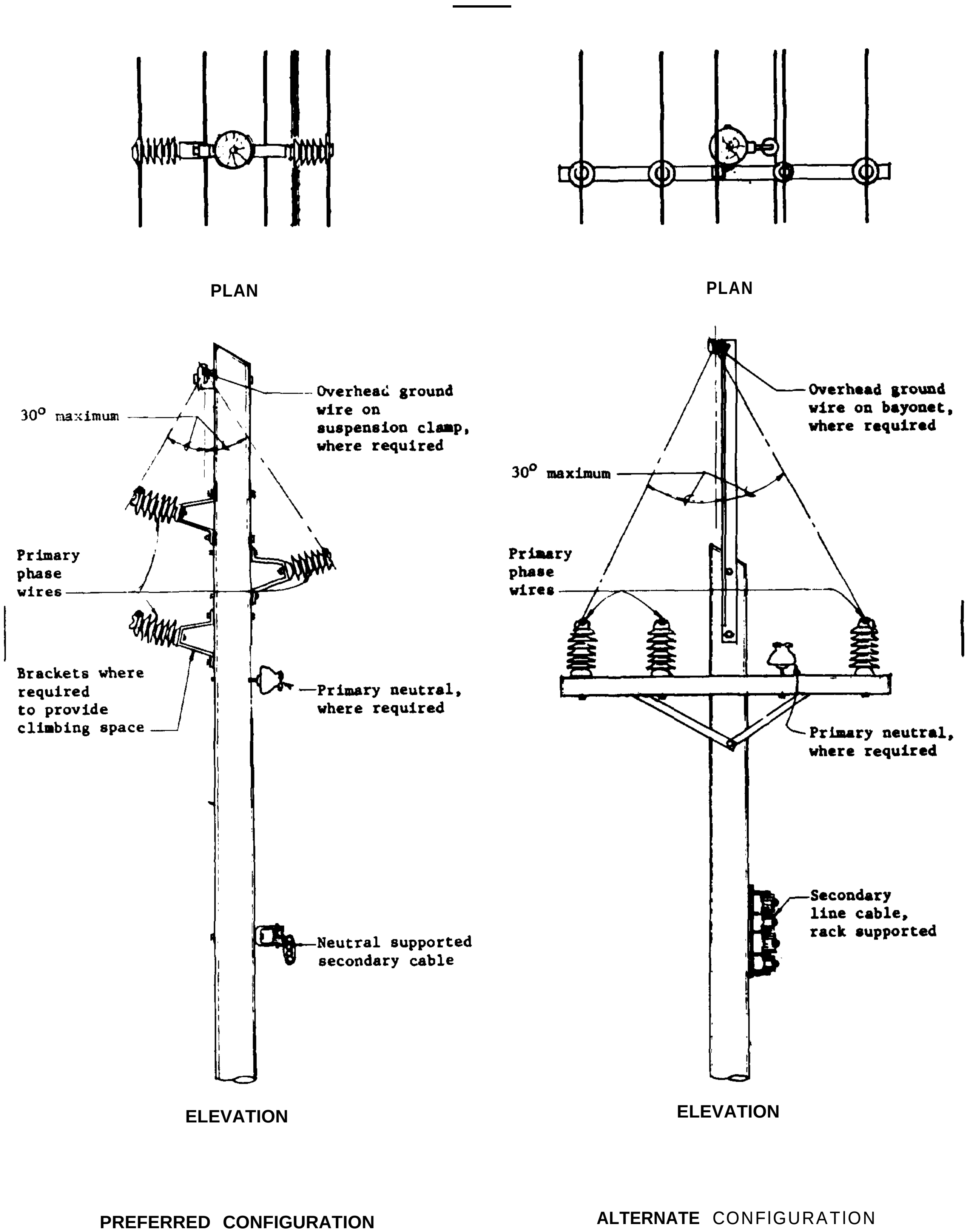


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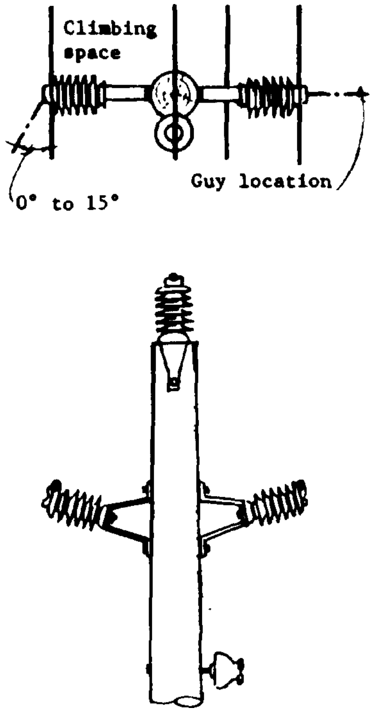
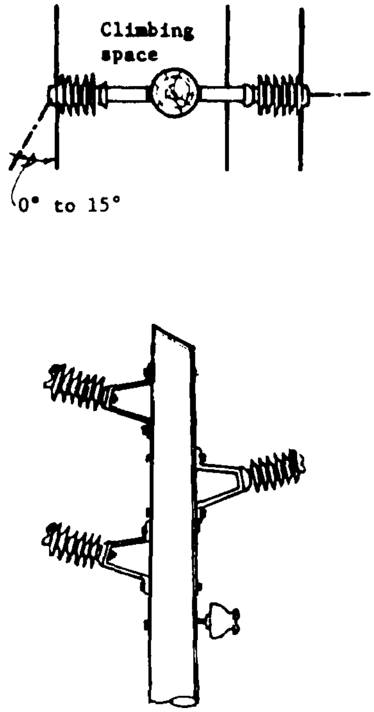
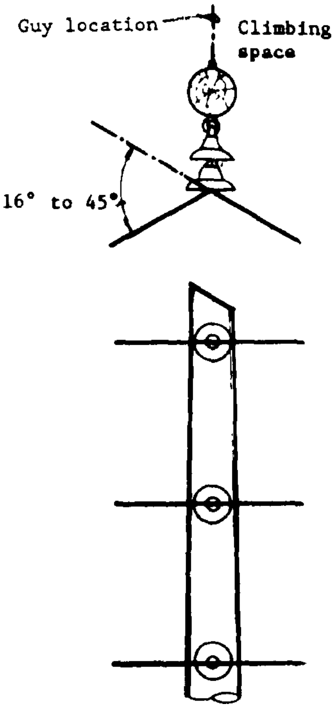
Figure 6-2. Tangent Construction Configurations.



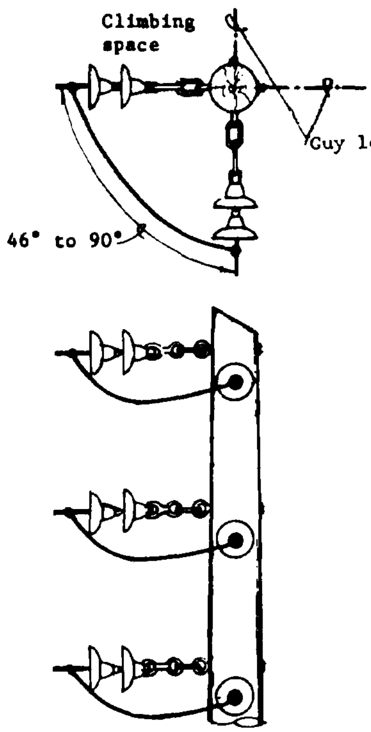
TRIANGULAR
TANGENT AND MINOR ANGLE



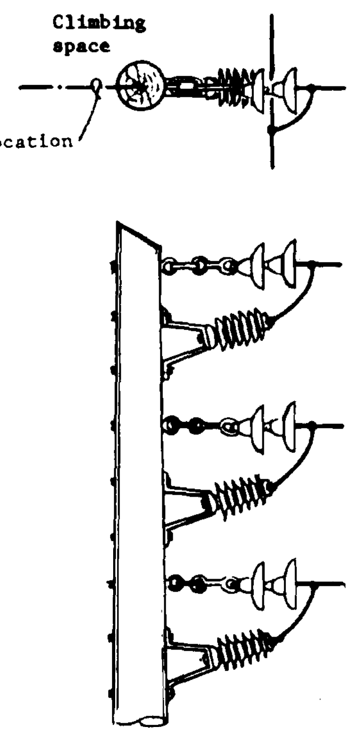
VERTICAL
TANGENT AND MINOR ANGLE



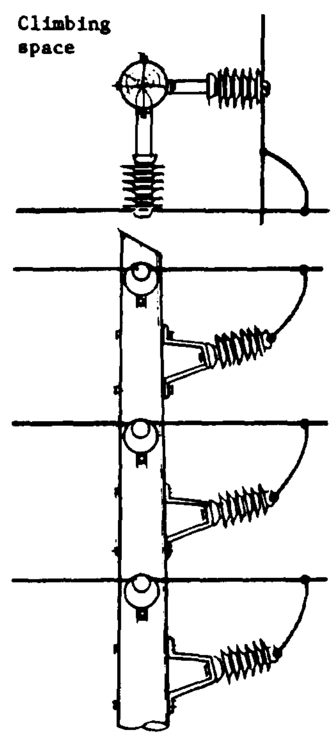
INTERMEDIATE ANGLE



'L' CORNER



'T'- CORNER



'X' CONNECTION

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Figure 6-3. Armless Configurations.

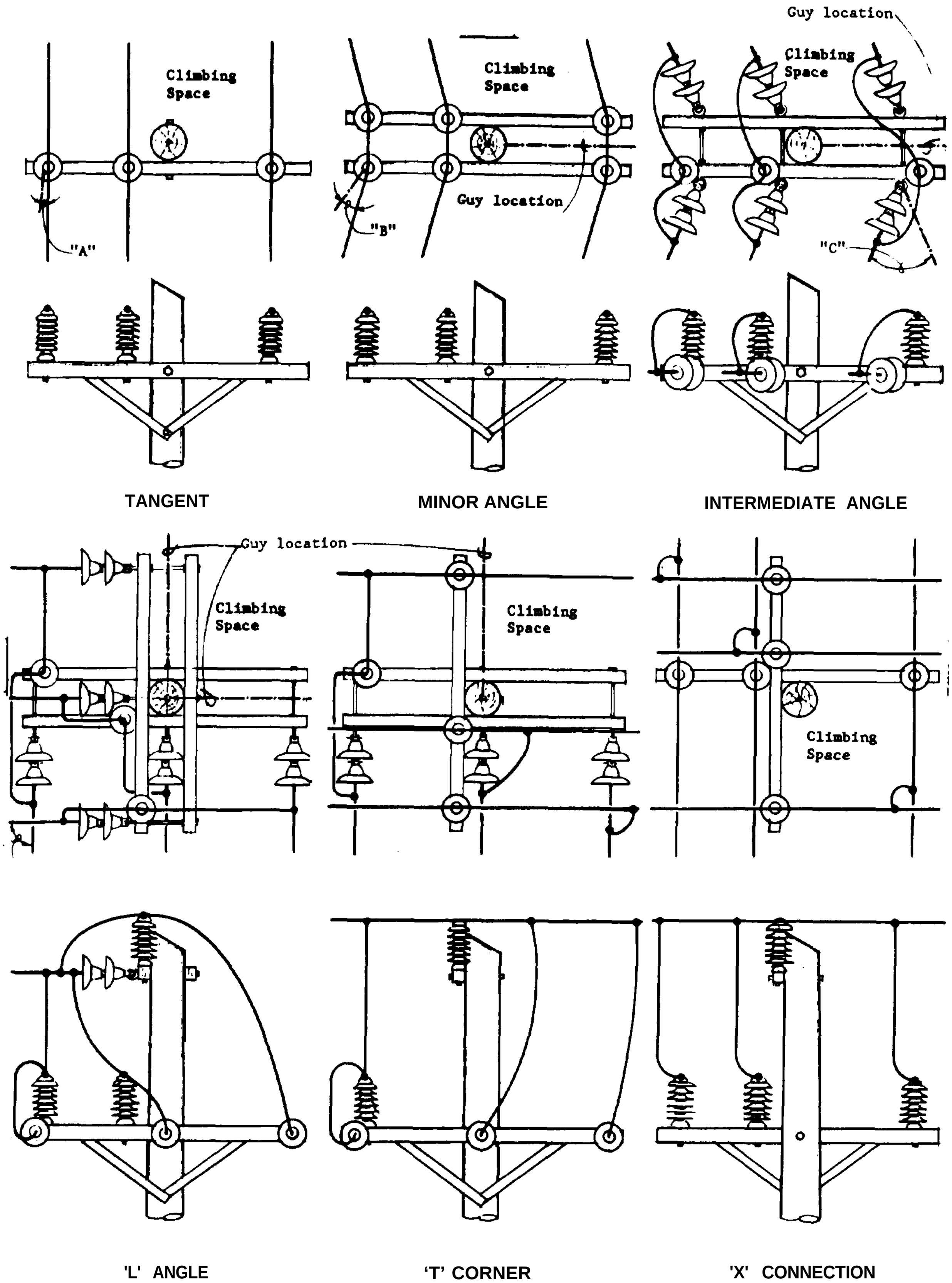

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Figure 6-4. Crossarm Configurations.

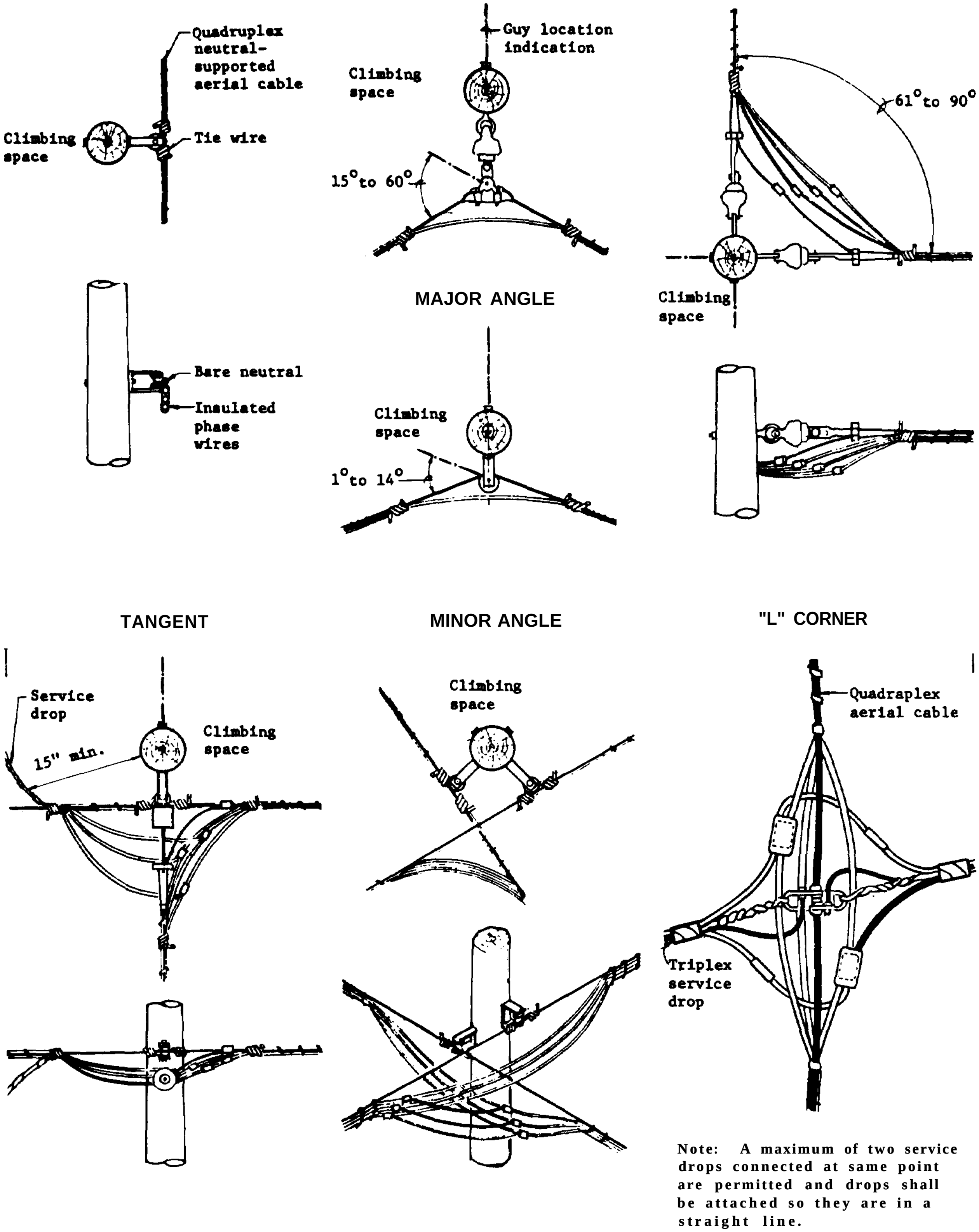

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Figure 6-5. Neutral-Supported Secondary Cable Configurations.

spool insulators for low-voltage circuits; and strain insulators for insulating guy wires. In crossarm construction, pin insulators may be used as a designer's option, but line-post insulators are superior in operation to corresponding pin types since line-post units are stronger, more resistant to vandalism, and inherently more radio-interference-free.

b. Classes. Selection of the class used is dependent upon operating voltage, strength requirements, and the degree of atmospheric pollution. Long periods without rain to wash off insulator contamination tend to aggravate the pollutant buildup problem. Selection of suitable insulator ratings will be based on local practice. Where lines are to be constructed on existing Government installations, that installation's experience or that of the serving utility will determine the insulation level used.

c. Dimensions. Figure 6-6 indicates dimensional ranges of insulators used. ANSI suspension Classes 52-3 and 52-4 have the same electrical, mechanical, and overall dimensions; but Class 52-3 has a ball-and-socket connection and Class 52-4 has a clevis eye connection. Selection of the type of connection provided is a matter of designer preference. Line-post insulators shown are either tie-top or clamp-top. The only difference between Class 57-1 and Class 57-11 is that Class 57-1 denotes a tie-top and Class 57-11 denotes a clamp-top. Tie-tops can be used for angles up to two degrees and clamp-tops are necessary for angles greater than fifteen degrees. For angles of three degrees to fifteen degrees, choice will be dependent upon mounting and loading requirements. Tie-top units are less expensive in cost, but a clamp-top eliminates both material and labor costs for the tie wire thus providing ease of installation. Where horizontal mounting is required there is, at present, no ANSI class; specifications therefore will indicate electrical, mechanical, and overall dimensions are the same as for the appropriate 57 subclass. Insulators with short studs (S) are used on armless configurations; those with long studs (L) are used on wood crossarm configurations.

d. Colors. Insulator colors available are brown and light gray. Light gray insulators will be used; however, in wooded areas or where lines are seen principally against hillside or tree-covered backgrounds, the brown glaze may provide a more acceptable appearance.

6-7. Guying.

Particular care will be taken to ensure that all points of strain in the pole lines are adequately guyed. Improperly or inadequately guyed lines soon begin to sag, degrading the reliability of the line as well as creating as unsightly installation and increased maintenance.

a. Components. A guy installation consists of various components as follows:

(1) *Guy wire (strand).* The strength of a guy installation is a function of the guy wire, the anchor, and the soil type. The rated breaking strength of the guy wire determines the requirements for all other components. Wire of either three or seven strands will be used. Each strand consists of a steel core having a protective coating of zinc, copper, or aluminum. Zinc coatings are available in standard ASTM coating weights. A Class A coating weight is half of a Class B coating weight and a third of a Class C coating weight. The coating weight used is dependent upon atmospheric corrosion with Class A used in dry or desert areas with little industrial contamination, Class C used in salt-laden or foggy areas or heavily contaminated locations, and Class B used elsewhere. Rated breaking strength used will be not less than 6,000 (6M) pounds. No more than two strengths of guys should be used for any one project. All guys will be sized for the maximum loading tension of the line.

(2) *Grounded* guys. Conductive poles such as steel or concrete, poles with overhead grounding conductors, and poles with guys connected to primary neutrals are considered grounded, since insertion of guy strain insulators does not isolate any portion of the pole from the ground.

(a) Connection to primary neutrals. For some installations, connection of primary neutrals to guys can improve secondary equipment protection. A detailed discussion of why this improvement is effected is given in REA Bulletin 83-1 which also covers the influence of such grounding on anchor rod corrosion. For other installations, such a connection may not meet local code requirements or will not be possible when the installation does not have a primary neutral system.

(b) Anchor corrosion. Corrosion can be a problem in systems that have primary neutrals interconnected with grounded guys when such systems are installed in areas having a low soil resistivity and a low ratio of buried steel to buried copper. In such cases, anchor rods and grounding electrodes will be of the same composition, either both of galvanized steel or both of copper-clad steel. The first installation is less expensive, but also provides more resistance. Choice of the anchor composition will be based on soil composition, resistivity, and corrosion properties. In highly corrosive soil conditions, anchor life has been extended by installing guy strain insulators in the

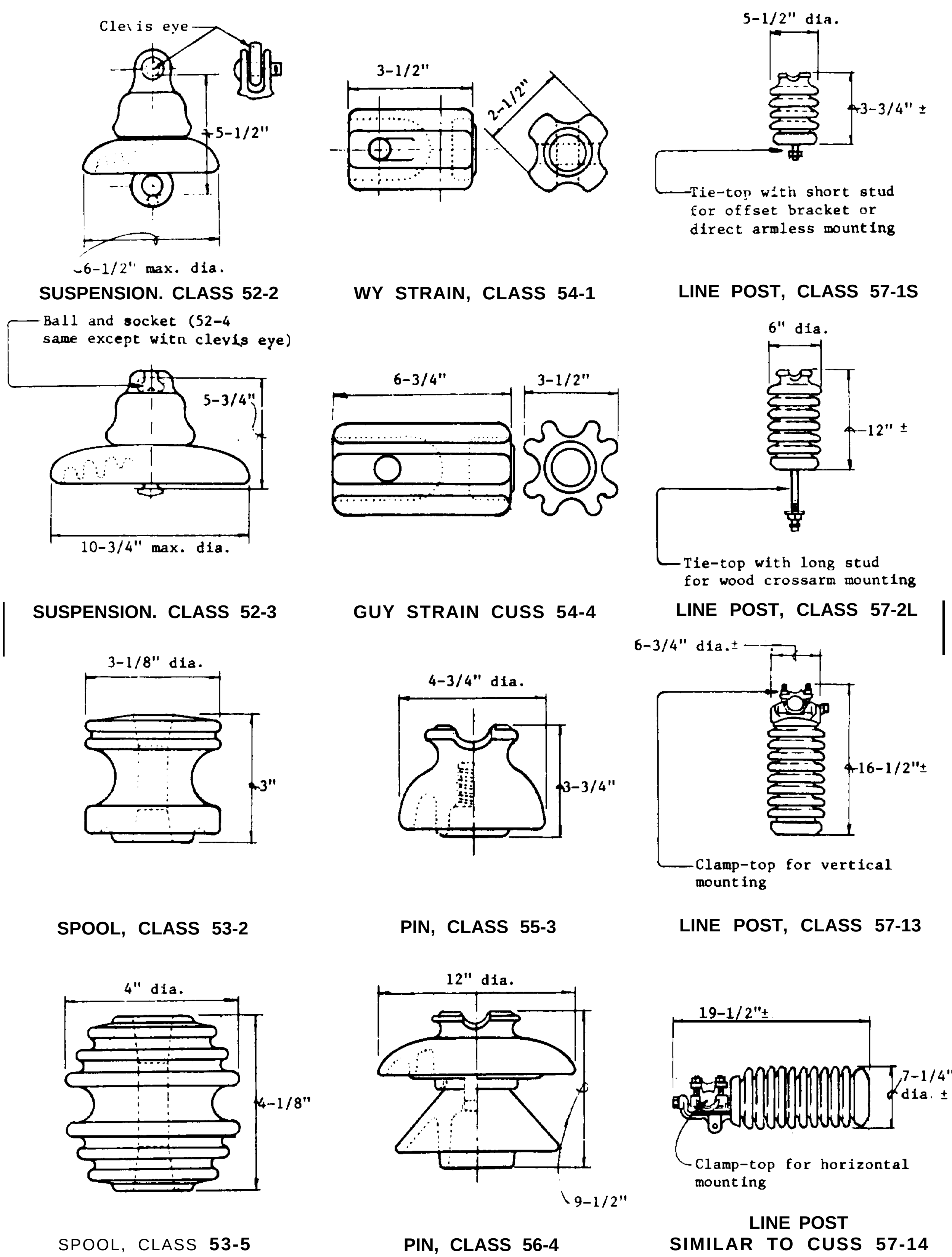

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Figure 6-6. Ranges of Insulator Dimensions.

guy wires. This isolates the anchor from the copper grounding systems installed at the poles. Furthermore, sacrificial magnesium anodes attached to the anchors may be cost effective.

(c) Grounding conductors and guy wires. Grounding conductors will always be copper regardless of the type of electrodes used. Guy wires will be of the same composition as electrodes and will be bonded to the hardware grounding conductor with approved clamps.

(3) *Nongrounded guys.* Where guy strain insulators are installed in a guy, to provide sectionalizing of grounded portions from nongrounded portions, that guy is considered ungrounded. Strain insulators will be provided in all guys on woodpoles, except where grounded guys are required or where local code requires sectionalizing in higher voltage lines.

(a) Strain insulator location. Insulators will be located in accordance with the NESC and so that in the event a guy wire is broken, the uninsulated upper portion of the guy wire cannot swing to any point less than eight feet above the ground. Insulators will be located at least six feet horizontally from the pole, which will provide separation between a lineman and the grounded guy wire segment. Where guy wires pass through line conductors or can fall on line conductors, additional insulators may be required.

(b) Strain insulator ratings. Ratings and strengths of insulators will be suitable for the circuit insulated. Since the maximum available ANSI guy strain insulator strength is 20,000 (20M) pounds this requirement could limit nongrounded guy strengths to 20M and may require two or more downguys if more than a 20,000 pound pull is necessary. Stronger insulators, which are not ANSI listed, may be used also.

(4) *Anchors.* The type of anchor used must provide suitable resistance to uplift and therefore is dependent upon soil conditions. Table 6-7 indicates suitable anchor types based on a range of soils from hard to soft. While the soil descriptions are not an industry standard, manufacturers are familiar with this or similar classifications. For the majority of cases, the most suitable anchor is an expanding type as shown on figure 6-7, because most lines are installed in ordinary soils. Strengths for available sizes of expanding anchors are also shown on figure 6-7. Rock or swamp anchors are described in manufacturer's catalogs. In the past, log anchors consisting of 8-inch to 12-inch diameter by 4-foot to 5-foot long creosoted logs, have been used in marshy soil. Since log anchors tend to rot, no matter how well creosoted or otherwise treated, their use is prohibited. Ex-

Type of anchor	General type	No.	Classification description
Rock	Hard	1	Solid bedrock
		2	Dense clay; compact gravel; dense fine sand; laminated rock; slate; schist; sandstone
		3	Shale; broken bedrock; hardpan; compact clay-gravel mixtures
Expanding	Ordinary	4	Gravel; compact garvel and sand; claypan
		5	Medium-firm clay; loose sand and gravel; compact coarse sand
Swamp or as suitable	Soft	6	Soft-plastic clay; loose coarse sand; clay silt; compact fine sand
		7	Fill; loose fine sand; wet clays; silt
		8	Swamp; marsh; saturated silt; humus

[a] Based on copyrighted data, courtesy of A. B. Chance Company, Centralia, Missouri and reprinted with its express written permission.

Table 6-7. Anchors Suitable for Various Soils.

panding anchors, with extra long anchor rods reaching firm underlying soil, may be acceptable in some cases. Multihelix screw anchors can also be installed in swampy soils when this type of anchor can provide the required holding power. Three-eye thimbles will be provided on all anchor rods. This permits use of individual down guys for primary, secondary, and communication circuits and anchors must provide adequate strength to support all of these loads.

(5) *Rod assemblies.* Rod assemblies must meet ANSI C135.2 tensile loading tests. A 5/8-inch diameter rod is rated at about 16,000 pounds breaking strength, a 3/4-inch diameter rod is rated at about 23,000 pounds, and a l-inch diameter rod is rated at about 36,000 pounds, but some manufacturers offer a 3/4-inch diameter rod rated at 25,000 pounds and a l-inch diameter rod rated at 40,000 pounds.

(6) *Guy markers.* The purpose of guy markers is to provide a substantial and conspicuous indication to pedestrians that an impediment to passage exists. Markers should be yellow to provide the greatest visibility, unless gray or other finishes are approved for the installation.

b. Installation. Guys are installed to balance line tensions and are therefore appropriate where lines begin, end, or where lines change direction.

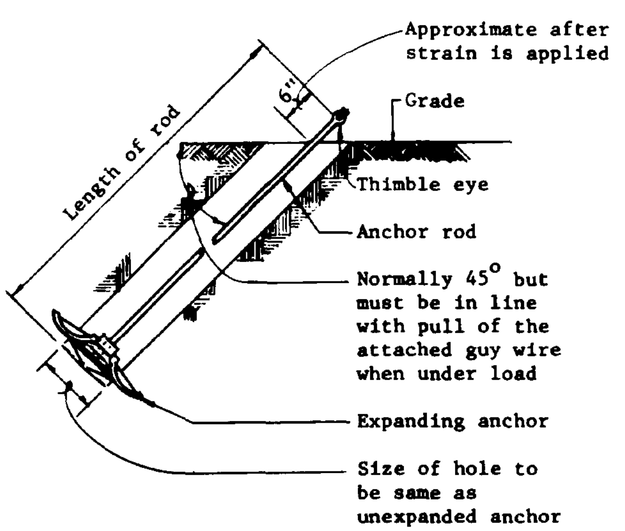
(1) *Types.* Most installations utilize down guys, wherein the guy wire is led away from the pole at a 45 degree angle down to an anchor. Since this configuration can interfere with traffic, span or sidewalk guys may be necessary to shorten guy leads. Head guys will be provided at heavily loaded corners to reduce tension in a corner span and strain on the corner pole. Dead-end guys will be provided in long straight lines at not less than every 2,500 feet to limit the effects from line breaks. Storm guys will be provided in long straight lines at not less than every 5,000 feet to reinforce lines against storm effects. Various types of guys are shown schematically on figure 6-8. Figure 6-9 shows down and span guy requirements in more detail. Although several guys are shown on the down guy detail, a single guy is permissible when adequate holding strength is provided.

(2) *Guy lead angle and strength requirements.* A lead angle (lead) is the angle that a guy wire makes with the center line of the pole. As can be seen on figure 6-10, the greater the lead angle the larger the horizontal component and thus the lower the minimum breaking strength needed to provide the necessary holding capacity to balance conductor tension. However, for down guys, the greater the lead angle the more the guy interferes with other use of the space. Lead angles from 45 degrees (optimum) to 15 degrees (minimum) will be used to balance conductor tensions of 70 to 25 percent of the guy wire minimum rated breaking strength. Where clearances over pedestrian areas require sidewalk guys, the holding capacity will be greatly decreased because there is a bending moment on the pole at strut height; therefore, sidewalk guys will be installed only when no other method is feasible or the conductor tension is minimal. A computation for in-line guy strength requirements is shown on figure 6-10. Figure 6-11 gives an example of a pole strength analysis.

(3) *Bisect angle guys versus in-line guys.* The maximum permitted angle of line deviation for a single angle guy installation (one guy installed on the bisect of line angle) is 45 degrees. For greater

Ratings[a]			
Holding power in ordinary soil pounds	Minimum anchor area square inches	Minimum rod diameter inches	Minimum rod length feet
6,000	90	5/8	7
8,000	100	5/8	7
10,000	120	3/4	8
12,000	135	3/4	8

[a]From REA Bulletin 43-5.



Note: Projection of anchor rods above grade may be increased to a maximum of 12 inches in planting beds or other locations where necessary to prevent burying the eye.

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Figure 6-7. Expanding Anchor Details.

angles, a down guy installation in line with each direction of pull is required.

6-8. Miscellaneous Items.

a. Pole line hardware. Hardware will be of a type specifically developed for pole line installation in accordance with industry standards. All steel or wrought iron hardware will be hot-dip galvanized as specified in ANSI C135.1.

b. Aerial line connector hardware. Copper line connector hardware will be of copper alloys and aluminum line connector hardware will be of aluminum or aluminum-lined alloys. Since bolted line connectors aggravates the cold-flow tendencies of aluminum conductors and cause maintenance problems, other types of connections such as compression type will be used.

c. Crossarms. Laminated wood, synthetic materials, and channel iron brackets are occasionally used for equipment crossarm type supports; however, it is only for unusual installations that the use of anything other than solid wood crossarms can be justified. Flat braces will be specified for 8-foot crossarms and angle braces for lo-foot crossarms to agree with REA construction. An angle brace is also required on 8-foot arms where conductors having a breaking strength of more than 4500 pounds. Extreme loading conditions may also warrant the extra cost of the stronger angle brace under other circumstances. Metal crossarm braces will reduce the effective BIL rating of the pole. In high lightning areas specify fiberglass braces.

d. Riser poles. Conduits on riser poles should be equipped with bushings to protect cables where they exit the conduit and to minimize water entry.

e. Fuse cutouts. Selection of fuse cutout duty will be based on the voltage of the circuit and the continuous and interrupting current ratings necessary for equipment or feeder protection. Ratings for fuses, fuse cutouts, and fuse links will comply with IEEE Stds C37.42, C37.46, and C37.47. Enclosed fuse cutouts are available only for 5.2 kV and 7.8 kV ratings, but not for ultra heavy duty applications. Open fuse cutouts are available for ratings of 7.8 kV and higher.

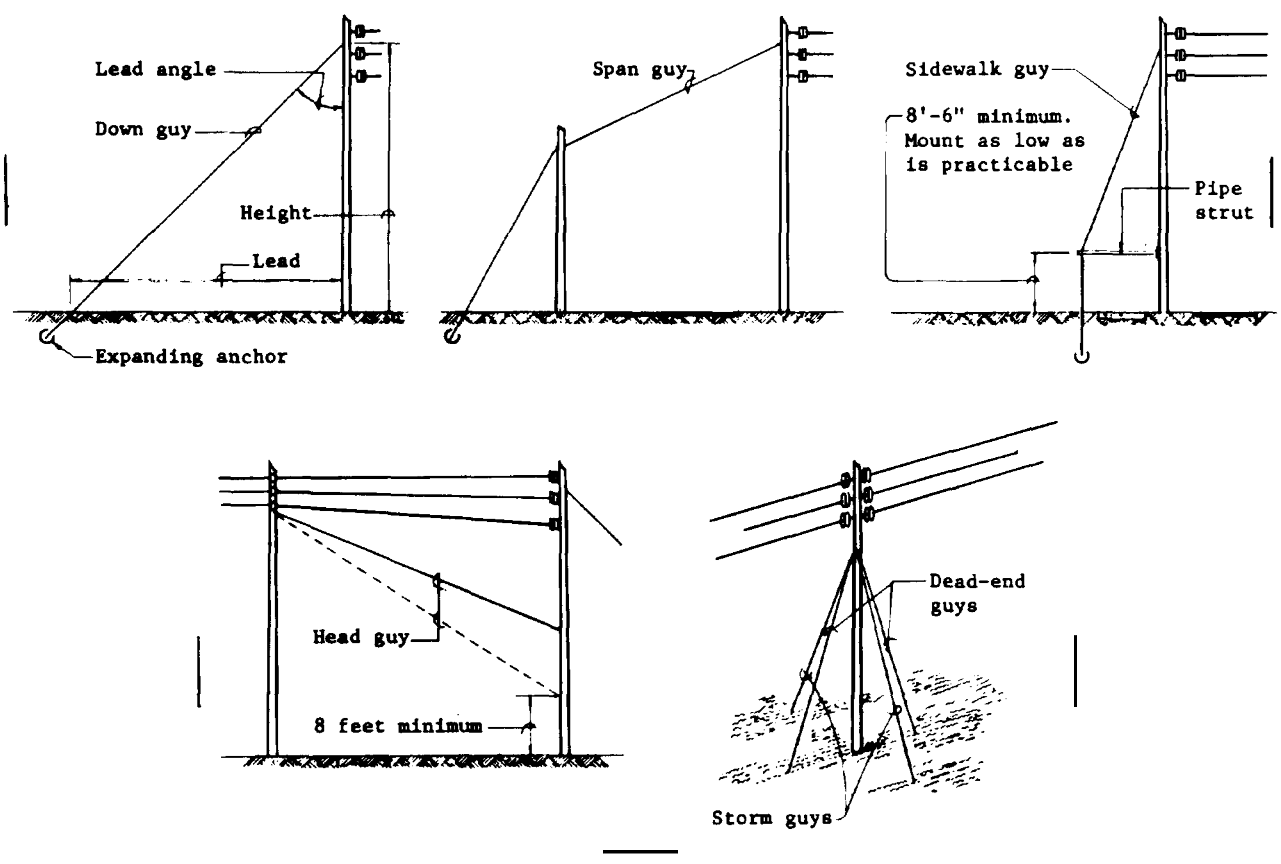

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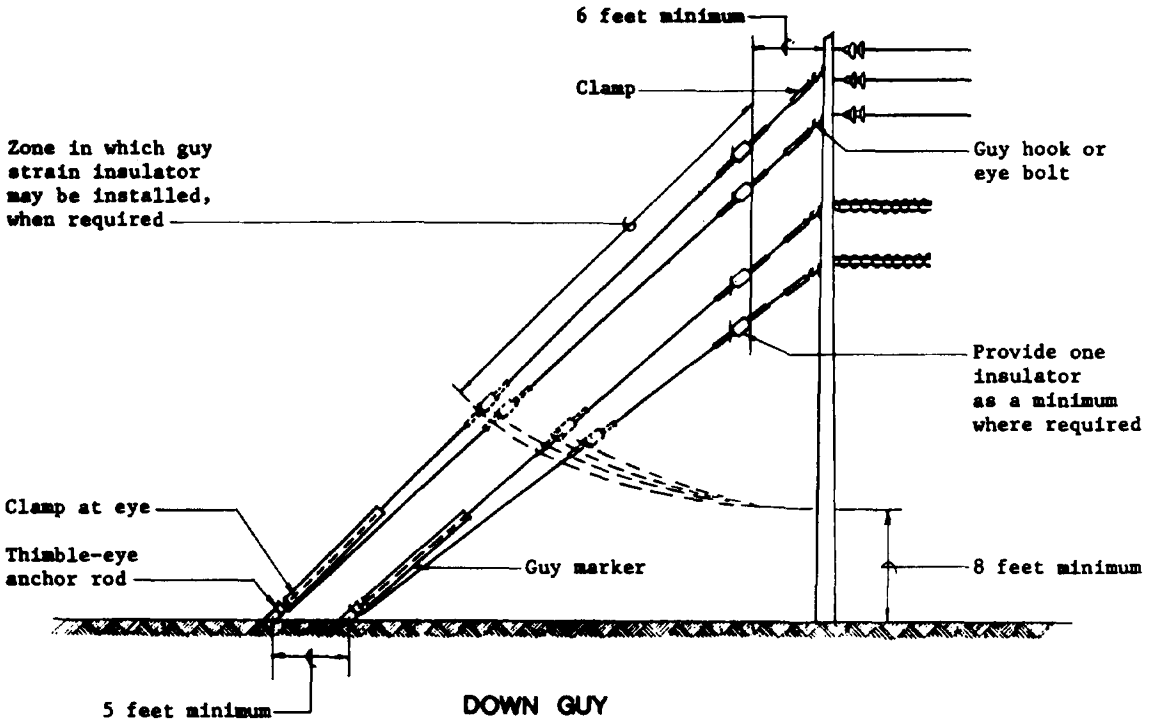
Figure 6-8. Types of Guy Installations



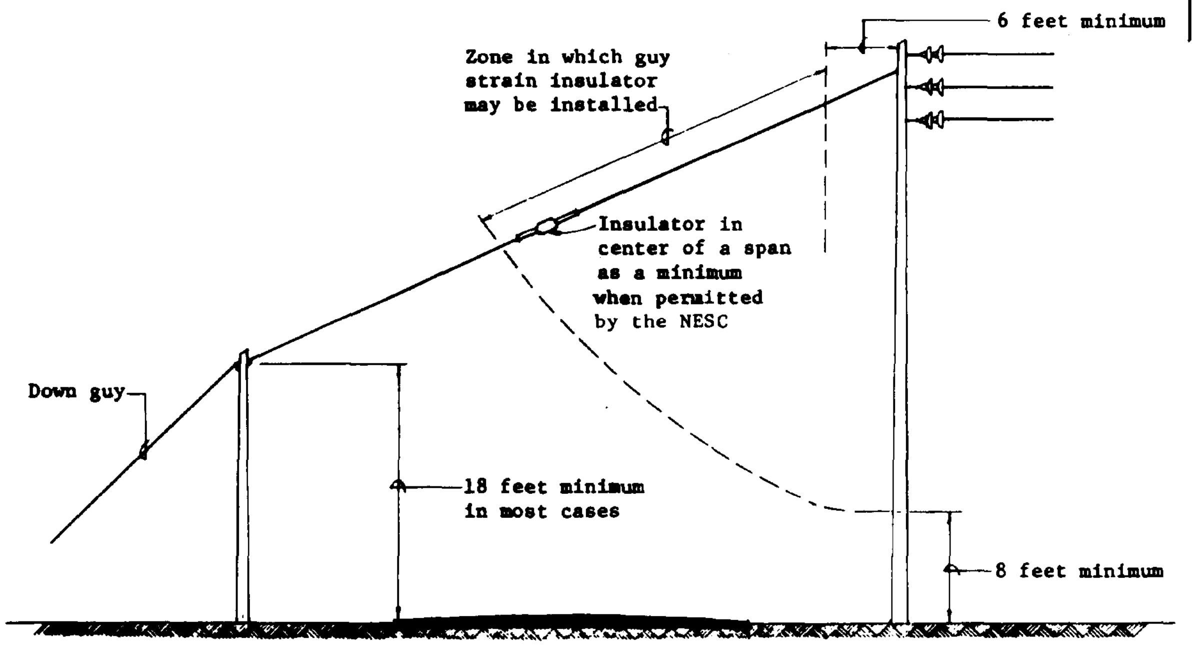


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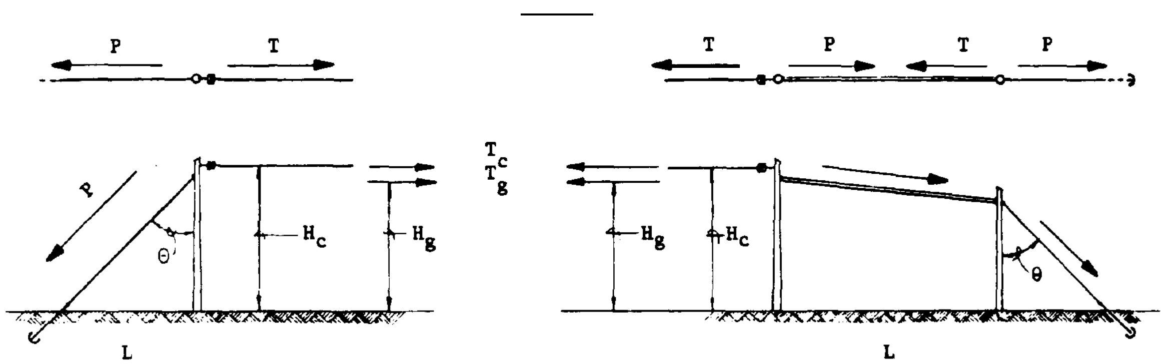
Figure 6-9. Guy Details.



USING VALUES BELOW

L = Guy lead H_g = Guy attachment height H_c = Conductor attachment height

Θ = Lead angle. T_c = Individual conductor tension at point of pole connection

T_g = Individual conductor tension at point of guy attachment

T = Total of all conductor tensions at point of guy attachment

P = Total pull on guy from all conductor tensions

IN FORMULAS BELOW

$T_g = (T_c) \times (H_c/H_g)$ (10-1)

$T = T_{g1} + T_{g2} + T_{g3} + ----$ (10-2)

Θ = Arc tangent L/H_g (10-3)

$P = T/\sin\Theta$ (10-4)

APPLY NESC FACTORS

Required guy strength = (P) x (Overload) ÷ (Safety) (10-5)

EXAMPLE

Given: Three No. 1 AWG copper-equivalent ACSR conductors installed in a light loading district in a vertical configuration with the guy connected at a lead angle of 45" and at the same height as the center conductor.

Then: T_c = 1,480 pounds a given in table 6-3 (10-1)

T = 3 x 1,480 pounds = 4,440 pounds (10-2)

P = 4,440 pounds ÷ 0.707 = 6,280 pounds (10-4)

Required guy strength = (6.280 x 1.5) ÷ 0.9 = 10,466 pounds (10-5)

Use: 3/8 inch, 7 strand, utilities grade, zinc-coated, steel strand with a minimum breaking strength of 11,500 pounds (ASTM A 475)

[a]Courtesy of Keller & Gannon

Figure 6-10. An Example of an In-Line Guy Strength Analysis.

USING VALUES BELOW **IN FORMULAS BELOW**

D_c = Conductor diameter (in)

D_n = Conductor plus NESC additional ice thickness requirement (in)

W = NESC wind pressure requirement (lb/ft^2)

L = Length of pole spacing (ft)

N = Number of conductors at same height above grade

H_c = Height of conductor above grade (ft)

M_c = Bending moment at base of pole from conductor (ft-lb)

P_t = Wind pressure on pole at the top[a]

P_g = Wind pressure on pole at the ground[a]

C_t = Circumference of pole at top (in)

C_g = Circumference of pole at grade (in)

H_t = Height of top of pole above grade (ft)

M_p = Bending moment at base of pole from wind on pole (ft-lb)

S_m = Section modulus at base of pole (in^3)

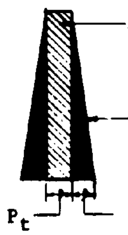
O_f = Overload factor from NESC table 261-3

F_s = Fiber stress in pole (lb/in^2)

$$D_n = D_c + (2 \times \text{ice thickness}^a) \quad \ldots\ldots \quad (1)$$

[a]Ice thickness from NESC table 250-1

$$M_c = \frac{D_n WLNH_c}{12} \quad \ldots\ldots\ldots\ldots \quad (2)$$



Force = $P_t \times H$ Moment arm = H/2

Moment = $P_t \dfrac{H^2}{2}$

Force = $1/2(P_g - P_t)(H)$ Moment arm = H/3

Moment = $(P_g - P_t) \dfrac{H^2}{6}$

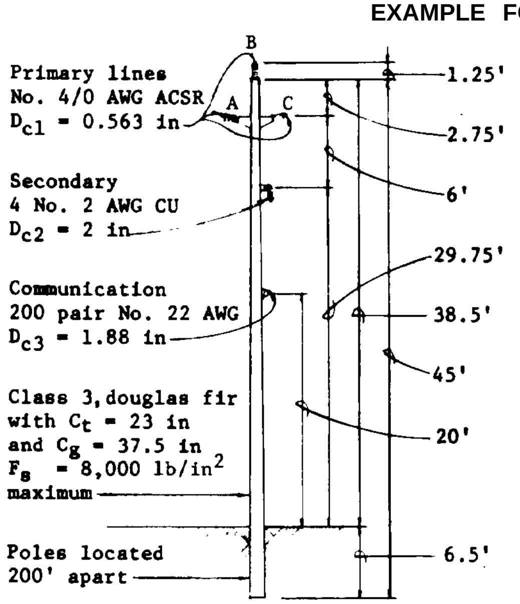
$$M_p = P_t\left(\frac{H^2}{2}\right) + \left(P_g - P_t\right)\left(\frac{H^2}{6}\right)$$

$$M_p = \frac{H_t^2 W}{72\pi}\left(2C_t + C_g\right) \quad \ldots\ldots\ldots\ldots \quad (3)$$

$$S_m = \frac{\pi}{4}\left(\frac{C_g}{2\pi}\right)^3 = \frac{C_g^3}{32\pi^2} \quad \ldots\ldots\ldots\ldots \quad (4)$$

$$F_s = \frac{12\left(M_c + M_p\right) O_f}{S_m} \quad \ldots\ldots\ldots\ldots \quad (5)$$

EXAMPLE FOR HEAVY LOADING DISTRICT



Check whether pole will carry load:

$D_n = D_c + 2(0.5)$ $D_{n1} = 1.563''$ $D_{n2} = 3''$ $D_{n3} = 2.88''$ (1)

$$M_c = \frac{D_n 4LNH_c}{12} = \frac{D_n LNH_c}{3} = \frac{(1.563)(200)(1)(39.75)}{3} + \frac{(1.563)(200)(2)(35.75)}{3} + \frac{(3)(200)(1)(29.75)}{3} + \frac{(2.88)(200)(1)(20)}{3}$$

$$= 21{,}380 \text{ ft-lb} \quad \ldots\ldots \quad (2)$$

$$M_p = \frac{H_t^2(4)}{72\pi}(2C_t + C_g) = \frac{H_t^2}{18\pi}(46 + 37.5)$$

$$= 2{,}190 \text{ ft-lb} \quad \ldots\ldots \quad (3)$$

$$S_m = \frac{(37.5)^3}{32\pi^2} = 167 \text{ in}^3 \quad \ldots\ldots\ldots\ldots \quad (4)$$

$$F_s = \frac{12\ (21{,}380 + 2{,}190) \times 4}{167} = 6{,}775 \text{ lb/in}^2 \quad \ldots \quad (5)$$

6,775 lb/in^2 < 8,000 lb/in^2: pole will carry load

[a]Lb per foot of circumferences

[b]Courtesy of Keller & Gannon

Figure 6-11. An Example of a Pole Strength Analysis.

6-9. Air Force Installations.

a. Reclosers and sectionalizers. Reclosers and sectionalizers shall be fully rated and coordinated. Electronically controlled reclosers are preferred over hydraulically controlled ones. Reclosers may utilize vacuum or oil as the interrupting medium. Sectionalizers shall be automatic loadbreak, manual recock, and installed only as an integral part of the system protection scheme. They should not be installed for switching purposes only. Stirrups should be installed as appropriate to prevent damage to main conductors at junction poles.

b. Radio interference. Where suppression of radio interference is critical, special considerations shall be given to contacts between current carrying conductors of dissimilar metals. The need for an interference-free environment may also necessitate the use of insulators coated or treated for radio noise suppression. Valve-type lightning arrester often cause radio interference and their use should be avoided. If required to suppress radio interference, utilize underground construction with transformers and equipment installed in grounded metal enclosures. High intensity discharge (HIS) lamps are also sources of high radio interference while filament lamps and low pressure sodium lamps are basically free of radio noise.

c. Arresters. Distribution class is preferred; consideration should be given to gapless types such as zinc oxide, metal oxide varistor (MOV).